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THE BLUE-SPOTTED SUNFISH

A CONTRIBUTION TO THE LIFE HISTORY AND HABITS OF *ENNEACANTHUS* WITH NOTES ON OTHER LEPOMINAE

By C. M. Breder, Jr.
New York Aquarium

and

A. C. Redmond
Hamilton College

Introduction

(Figs. 322–331 incl.)

Considering how well known most of the lesser sunfishes are it is surprising that little of a detailed nature concerning their life histories has found its way into scientific literature. Therefore, when the opportunity arose to make some connected field observations, chiefly on *Enneacanthus* advantage was taken of it. The field work was carried on at the Wyanokie Zoological Station, located at Haskell, New Jersey about thirty miles north-west of New York City. Most of the actual work of collecting and the making of field observations was done during 1928 by Redmond.

Specific Status

Although it is not the purpose of the present paper to consider the relationships of *Enneacanthus gloriosus* (Holbrook) and *Enneacanthus obesus* (Baird) if indeed these two species are distinct, to prevent confusion it is obviously desirable to clearly define the species to which this study refers.

From an examination of the rather large series both living and preserved, which we handled, it became evident that we were concerned with a single species of a rather variable nature, part of which appeared to be individual, part sexual and part age. On a basis of this material alone references to the literature gave us reason to believe that the two species were synonymous as Palmer & Wright 1920 suggest. However, Dr. C. L. Hubbs, while at the Museum of Comparative Zoology, kindly compared samples of our material with specimens there and doubts that they are the same. Without going into the matter further it is clear that our material is referable to *Enneacanthus gloriosus* (Holbrook) whether the two are eventually synonymized or not.

The Environment

At first glance, the body of water in which the present studies were made appears to be rather different than a closer inspection proves it to be. It is a small stream, possibly averaging about eight feet in width, known as Post Brook, that for long stretches gurgles over and under great broken chunks of basaltic rock through fairly dense woodland (Fig. 322*a*). Here and there are quiet pools of various sizes up to about 200 by 500 feet. In places there are clearings that allow meadow land to reach to the waters edge. In such places the banks are lined with alders, birches, willow, choke cherries and various other shrubs (Fig. 322*b*). The bottom is usually either rocky or sandy but in some places there is a considerable amount of alluvial silt accumulated. The current and height of water is exceedingly variable. Pickerel weed, arrow-head, *Fontinalis*, *Elodea* and similar aquatic plants grow for the most part rather sparsely in the quiet pools when these occur in clearings. Throughout the more rapid and usually wooded portions there is little but a sparse growth of algae.

In brief, the stream would be designated as a typical trout stream and such it was in not very remote historic times. Today, however, not only are trout absent therefrom but they are replaced practically entirely by the typical pond fishes. Probably only one of its species, *Boleosoma olmstedi*, which is rare, could be considered as a stream preferring species. A list is given (Table 1) of three years of more or less systematic collecting in this stream and we believe it to be complete for the length covered.

This change in the fish fauna of Post Brook is doubtless associated with the change in environmental conditions brought about by the building of artificial lakes. One immediately above the Zoological Station, Lake Iosco, of some sixty-five acres, allows of considerable warming of the water entering the stream below it. Also this lake purges or "blooms" in the heat of summer to such an extent that the brook itself becomes a thick suspension of *Anabena* and related organisms. The oxygen content drops to a low concentration at times, especially when the cycle of these organisms

TABLE I

Fishes inhabiting Post Brook

1. *Ameiurus nebulosus* (Le Sueur)
2. *Catostomus commersonii* (Lacépède)
3. *Erimyzon sucetta oblongus* (Mitchill)
4. *Abramis crysoleucas* (Mitchill)
5. *Notropis bifrenatus* (Cope)
6. *Anguilla rostrata* (Le Sueur)
7. *Umbra pygmaea* (De Kay)
8. *Esox reticulatus* (Le Sueur)
9. *Pomoxis sparoides* (Lacépède)
10. *Acantharchus pomotis* (Baird)
11. *Ambloplites rupestris* (Rafinesque)
12. *Enneacanthus gloriosus* (Holbrook)
13. *Lepomis auritus* (Linnaeus)
14. *Eupomotis gibbosus* (Linnaeus)
15. *Micropterus salmoides* (Lacépède)
16. *Micropterus dolomieu* (Lacépède)
17. *Perca flavescens* (Mitchill)
18. *Boleosoma nigrum olmstedi* (Storer)

is on the wane and they are oxidizing rapidly. The pH values of the stream do not show any marked changes, probably not enough to be inimical to trout. The factors involved that have rendered this stream unfit for trout and similar fishes we believe to be referable indirectly to the raising of the temperature by the construction of artificial lakes, and to the oxygen consuming agency of the organisms which reduce the oxygen concentration at times below that necessary for trouts. See Breder 1927 for further discussion of this interrelation. A graph (Fig. 323) gives such data on temperature et cetera as was gathered during the work.

As was to be expected, these properly pond fishes were concentrated in the quiet pools and the gurgling stretches between were relatively barren of fish life. Most of the work was carried on in a pool just opposite the Haskell Railroad Station. This point also marked our lowest point of study, while the dam retaining Lake Iosco marked our upstream limit. Unless otherwise specified all data refers to this lower pool represented by Fig. 322*b*.

On several occasions systematic collections were made in this pool from which the relative frequency of the various species was calculated. This is given in Table 2. The figures were obtained by dividing the number of individuals of a species by the total number of hauls made. A forty foot seine of ¼″ square mesh was used and in all cases it was operated in a similar manner.

This pool is shored to a considerable extent by cinders from the nearby railroad embankment. This cinder floor runs out into the pond for some distance where it is replaced by the natural rather clayey soil of the region. A variety of vegetation lines the banks

TABLE II. FREQUENCY OF SPECIES

LOWER POOL. JUNE 21

Species	Seine Hauls								Total	Frequency
Micropterus dolomieu	0	1	0						1	.33
Acantharchus pomotis	0	1	0						1	.33
Enneacanthus gloriosus	2	0	0						2	.66
Erimyzon succeta oblongus	3	0	0						3	1.00
Ameiurus nebulosus	3	0	3						6	2.00
Esox reticulatus	0	3	5						8	2.66
Abramis crysoleucas	100	0	12						112	37.00

LOWER POOL. JULY 21

Species	Seine Hauls								Total	Frequency
Catostomus commersonii	0	0	0	0	0	0	1	0	1	.13
Umbra pygmaea	0	0	1	0	1	0	0	0	2	.25
Erimyzon succeta oblongus	0	0	0	1	2	0	0	0	3	.28
Abramis crysoleucas	0	4	1	0	1	0	0	0	6	.75
Mycropterus salmoides	0	3	1	0	1	1	1	0	7	.88
Acantharchus pomotis	1	3	2	2	0	1	4	0	13	1.63
Esox reticulatus	2	0	2	1	5	7	3	2	22	2.76
Enneacanthus gloriosus	4	4	2	4	1	7	11	1	34	4.25
Ameiurus nebulosus	1	0	0	0	1*	1	2	0	5	.62

UPPER POOL. JULY 16

Species	Seine Hauls								Total	Frequency
Catostomus commersonii	1	0	0	0					1	.25
Eupomotis gibbosus	1	0	1	0					2	.50
Erimyzon succeta oblongus	1	0	1	0					2	.50
Ameiurus nebulosus	0	0	3	0					3	.75
Esox reticulatus	2	0	4	1					7	1.75
Abramis crysoleucas	75	10	15	20					120	30.00
Enneacanthus gloriosus	Only 3 specimens all summer									

*Also a school of very young. These would bring the total to 72 + and the frequency to 9.0 +. Note that *Eupomotis gibbosus* was absent from the lower pool on both these dates.

while parts of the pool are fairly choked by submerged aquatics. An indication of the types and locations of the various species is given in Fig. 324. A black muck of decaying vegetation covers the pond bottom in places.

The chief habitat of *Enneacanthus* here was in a fairly dense stand of *Potomogeton epihydrus* about fifteen feet off shore in a depth of three or four feet. This area is indicated in Fig. 324 by the dotted line. Further off shore the pool descended to a considerably greater depth (possibly six feet on the average) and here there was not much shelter of this sort. In this open water *Abramis* disported itself.

The current under the railroad bridge was measured as being ten feet per minute and eight feet per minute at the lower outlet, but there was no appreciable current in the cove that *Enneacanthus* found suitable as a habitat. These figures varied with each local rain storm.

This pool at the beginning of these observations contained large numbers of *Abramis* but these later disappeared, possibly by the inadvertent destruction of their cover. These centered in the more shallow places where there was but a sparse growth of *Potomogeton* just below the railroad bridge.

Food

There is little definite data on the food of *Enneacanthus*. Abbott 1883 reports, "In every case the stomach was empty, but the intestine contained tracheae, eyes, elytra, heads and chitinous parts of small aquatic beetles. These were very numerous, also *Psidium* sp. occasional; several small univalve mollusks; a few Chironomus larvae; a few fragments of insects; many *Cyclops;* a few very small univalve mollusks and a single water mite." This data refers to southern New Jersey.

Hildebrand & Schroeder 1928 record the following from the brackish affluents of Chesapeake Bay. "The food of this fish, according to the contents of thirteen stomachs examined, consists largely of small crustaceans—that is, copepods, amphipods, and isopods. Insects and worms, too, were present in a few stomachs; also fragments of plants."

The following data (Table 3) gives the results of the examination of the stomach contents of a series of specimens from Post Brook.

TABLE III. STOMACH CONTENTS

Enreacanthus gloriosus					Foods						
S. l. mm.	Sex	Condition	Stomach	Intestine	Nemathel-minthes	Gaster-opoda	Daphnia	Ostracod	Cyclops	Asellus	Amphipod
58	M	Mature	....	....	..	..	..	..	..	..	..
57	M	"	....	....	..	..	..	1	..	..	..
56	M	"	....	....	..	..	..	..	..	..	..
55	M	"	....	....	..	..	..	20	..	..	..
53	M	"	....	....	..	..	..	..	..	5	5
53	M	"	Empty	....	..	..	..	..	..	..	..
52	M	"	....	Empty	..	..	..	..	..	..	80
49	F	"	....	....	..	5	+	35	..	..	30
49	F	"	....	....	..	..	..	..	..	..	..
48	F	"	Full	....	..	..	..	..	..	..	25
48	M	"	Empty	....	..	..	..	+	..	15	+
47	F	"	....	....	..	..	2	5	..	..	30
47	F	"	....	....	..	..	..	+	..	..	+
46	M	"	....	....	..	..	..	..	..	..	50
43	F	"	....	....	..	..	..	..	..	..	..
42	F	"	....	....	..	5	..	10	..	..	..
41	M	"	....	....	..	..	..	5	..	15	..
41	M	"	....	....	..	..	..	..	..	..	85
40	M	"	....	....	..	..	..	..	..	..	70
40	M	"	....	....	..	..	+	+	..	+	10
40	M	"	....	....	..	50	..	10	..	..	10
40	M	"	Empty	Half full	..	..	..	+	..	..	..
38	M	Immature	....	....	..	..	..	..	..	..	15
37	F	"	....	....	..	..	+	..	..	..	70
				Average	..	2.4	+	3.4	..	1.5	19
Eupomotis gibbosus											
68	F	Immature	....	....	..	..	..	10	..	40	35
65	M	"	Empty	Empty	..	..	..	..	..	..	..
62	F	"	....	....	..	1	..	70	..	5	..
58	M	"	....	....	..	..	..	..	..	1	1
57	F	"	....	....	..	..	..	80	..	..	5
56	F	"	Empty	....	..	..	..	50	..	..	..
56	F	"	....	....	..	..	..	60	..	..	20
55	F	"	....	....	..	..	..	5	..	..	5
54	M	"	....	....	..	..	..	..	..	..	..
53	F	"	Full	....	..	+	..	15	..	..	25
52	F	"	....	....	2	..	..	15	..	..	35
52	M	"	....	....	..	..	..	+	..	+	25
52	F	"	Empty	....	..	..	..	..	..	..	..
51	F	"	....	....	..	..	..	25	1	..	..
51	M	"	Half full	....	..	..	+	..	..	..	..
50	F	"	....	....	..	..	1	80	..	5	5
50	M	"	....	....	..	..	..	60	..	..	10
45	F	"	....	....	1	..	..	90	..	2	..
43	F	"	....	....	..	..	..	5	..	..	..
43	F	"	....	....	..	..	..	5	..	..	50
42	F	"	....	....	..	..	..	..	..	..	45
41	F	"	....	....	..	..	..	+	..	..	..
41	—	"	....	....	..	..	..	5	..	..	..
38	F	"	....	....	..	..	..	5	..	..	..
38	F	"	Full	Full	..	..	..	..	..	..	..
36	?	"	Full	....	..	..	..	70	..	..	..
33	F?	"	Empty	Full	..	..	..	10	..	..	..
				Average	+	+	+	22.2	+	2	9.2

TABLE III. STOMACH CONTENTS—*Continued*

Foods—*Continued*												
Odonata	Plecoptera	Corixia	Coleoptera	Diptera	Chirono-mous	Ant.	Arachnid	Nydrach-nida	Anabaena	Potomoge-ton	Unrecog-nizable	Remarks
..	..	100	..	..	..	..	..	..	..	..	..	About 30 per cent. full.
5	75	..	..	..	..	..	..	..	..	..	19	Triturated animal matter.
90	..	..	..	..	..	..	..	..	..	+	10	Triturated plant matter.
..	..	..	..	..	15	..	..	..	..	..	60	Veg. and animal remains.
40	..	30	..	..	15	..	..	..	..	..	5	Animal remains.
+	..	..	..	..	+	..	..	..	..	..	..	Stomach nearly empty.
..	..	..	..	..	..	..	..	..	+	..	20	Nearly empty.
..	..	..	..	..	10	..	..	..	..	..	20	Animal remains.
80	..	..	..	..	5	..	..	..	..	..	15	Animal remains.
60	..	..	..	..	10	..	..	..	..	..	5	Animal remains.
..	..	..	..	..	+	..	..	..	..	+	85	Animal and plant remains.
30	..	..	..	..	10	..	..	+	..	..	23	Animal remains.
50	..	..	25	..	20	..	..	..	..	..	..	
40	..	..	5	..	+	..	..	..	..	..	5	Animal remains.
..	..	97	..	..	3	..	..	..	..	..	..	Much digested.
..	..	..	..	..	30	..	..	..	..	..	55	Animal remains.
..	..	70	..	..	..	..	..	..	..	..	10	Full.
..	..	..	..	..	..	..	..	..	..	..	15	Animal remains.
10	..	..	..	+	10	..	..	..	..	..	10	Animal remains.
..	..	..	..	..	..	..	..	..	..	..	80	Crustacean remains.
..	..	..	..	..	10	..	..	..	..	..	20	Animal remains.
..	..	90	..	..	..	..	..	..	..	..	8	Animal remains.
..	..	..	..	20	50	..	..	..	..	..	15	Animal remains.
..	..	..	..	..	15	..	..	..	..	..	15	Animal remains.
16	3	16	1	.8	8	..	..	+	+	+	20	
..	..	..	..	..	5	..	..	..	..	..	10	Animal remains.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	24	Veg. and animal remains.
..	..	6	..	..	30	..	..	..	..	..	8	Mostly crustacean remains.
..	..	..	..	..	5	..	..	..	..	..	10	Probably ostracods.
..	..	..	..	..	1	..	..	..	..	..	50	Veg. remains.
..	..	..	..	..	5	..	..	..	..	..	15	Veg. remains.
..	..	..	..	..	10	..	60	..	..	..	5	Veg. and crustacean remains.
..	..	..	..	..	100	..	..	..	..	..	..	3 Chironomids only.
..	..	..	..	..	60	..	..	..	..	..	..	
3	..	..	..	..	40	..	..	..	..	..	5	Veg. and
..	..	..	..	10	..	15	..	..	..	..	50	Animal remains.
..	..	..	..	..	100	..	..	..	..	..	..	2 Chironomids in intestine only.
..	..	..	..	5	55	..	..	..	..	..	14	Veg. remains.
..	..	..	..	..	+							
..	..	..	..	..	2	..	..	..	..	..	7	Probably ostracods.
..	..	..	..	..	5	..	..	..	..	..	25	
..	..	..	..	..	+	..	..	..	..	..	7	Probably ostracods.
..	..	..	..	..	..	..	..	..	..	..	95	Too far digested to identify.
..	..	..	..	..	10	..	..	..	..	..	40	Too far digested to identify.
..	..	..	..	..	45	..	..	..	..	..	5	Animal remains.
..	..	..	..	..	+	..	..	..	..	..	80	Too far digested to identify.
..	..	..	..	..	40	..	..	..	..	..	55	Too far digested to identify.
..	..	..	..	..	80	..	..	..	..	..	15	Unidentifiable algae.
..	..	..	..	..	100							
..	..	..	..	..	20	..	..	..	..	..	10	Too far digested to identify.
..	..	..	..	..	80	..	..	..	..	..	10	Veg. and animal remains.
+	..	2.2	..	1	35	1	1	..	..	..	22	

It is evident from the nature of the bulk of this food that *Enneacanthus* must spend considerable time in picking around the dense foliage of its chosen habitat. Although in an aquarium they will dart out from cover to take almost any small organism offered them they quickly return. Also as net hauls in open water, not dragged through such weeds, were usually barren of these fishes we infer that they never normally wander very far from such shelter. Other observations in a thickly planted aquarium showed that they would cruise about amid the weeds until they saw some motion on the part of a small organism clinging to the plants, and then rush up and snatch it. These weeds in the pond were usually lightly covered with fine silt brought down by rains which doubtlessly accounts for such material and fragments of plants found in the stomachs. Very likely such material was accidentally ingested along with the other foods, proper. At times in the aquarium they showed no aversion to feeding at the surface. This was probably a more or less acquired habit for at first they would not rise but later did so freely when accustomed to having food always introduced from above.

Compared with *Eupomotis gibbosus* of similar size their feeding habits seem to be somewhat different. A collection of twenty-five each of similar size made on September 10 showed *Enneacanthus* to be the more voracious of the two. It was also found that they "masticated" their food to a much finer degree than did *Eupomotis*. In all but six *Enneacanthus* the stomachs were found to be empty and material could be found only in the intestine, already well digested, whereas in *Eupomotis* both stomach and intestine usually contained food. As this collection was made about three days after a heavy rain and subsequent high water it is possible that the *Enneacanthus* had gorged themselves on organisms washed out by the downpour. This would suggest some difference in reaction to swollen streams by the two species. It is also related to the relative speed of digestion, efficiency of peristolsis *et cetera* in the two.

Sexual Differences

The mature males average a little deeper bodied and longer finned than the others. Their usual ground color is a very pale olive and there is a bright greenish spot in the center of nearly each scale. These spots along the sides form a series of dotted lines.

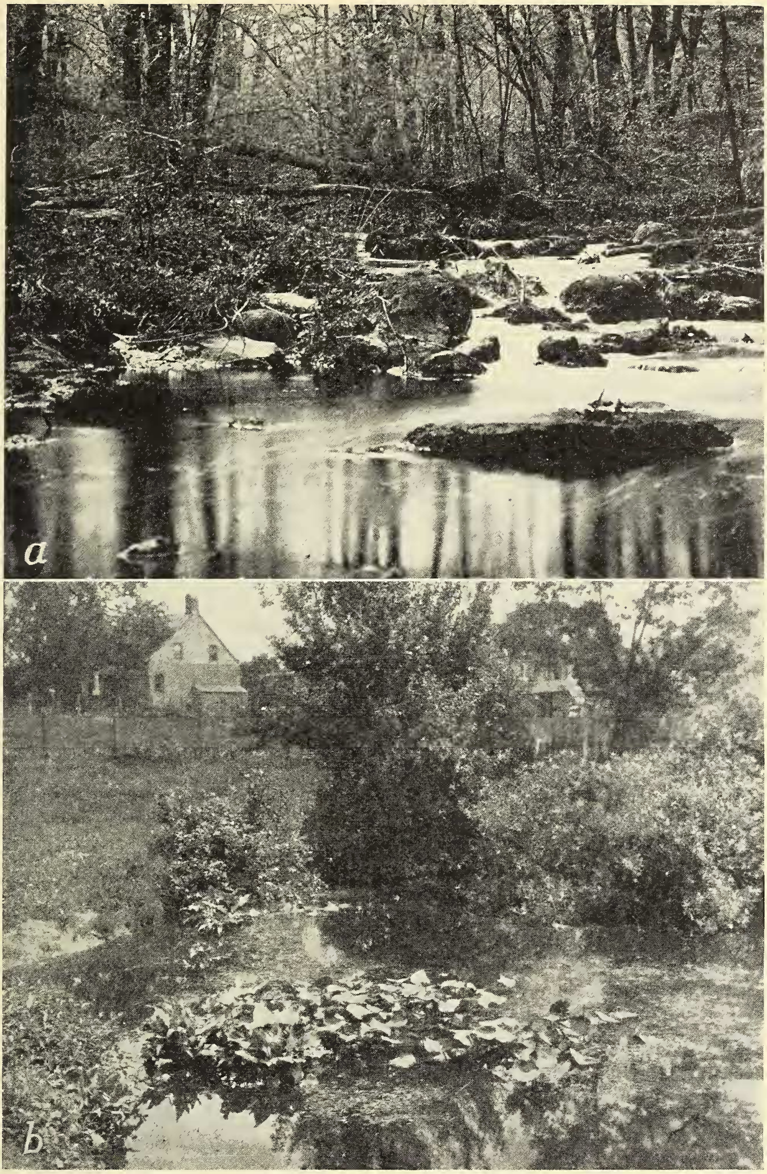


Fig. 322. *a.* Scene along Post Brook passing through woodland. *b.* Pool where most of the studies were carried on.

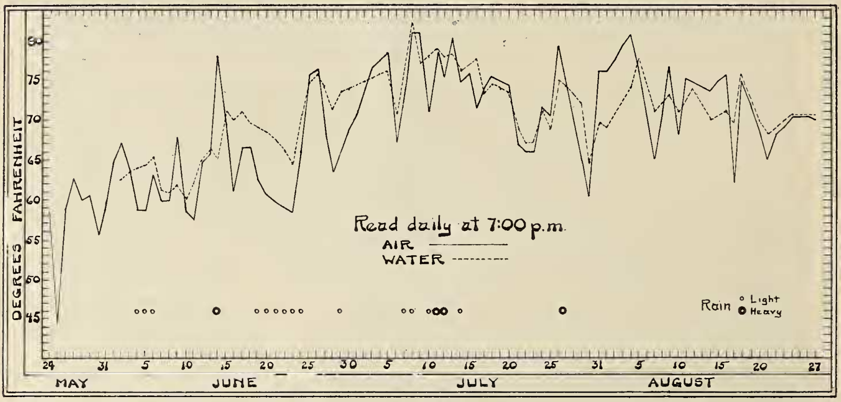


Fig. 323. Chart showing temperature and rainfall.

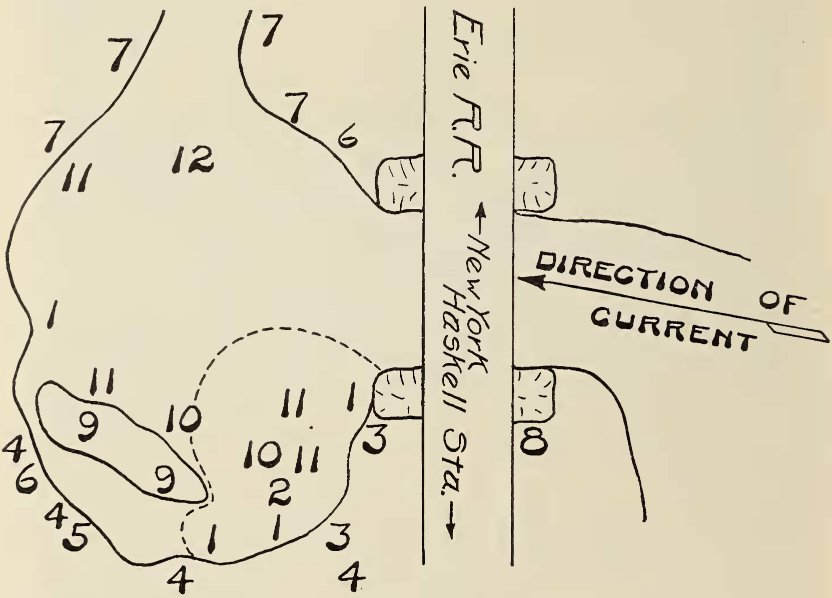
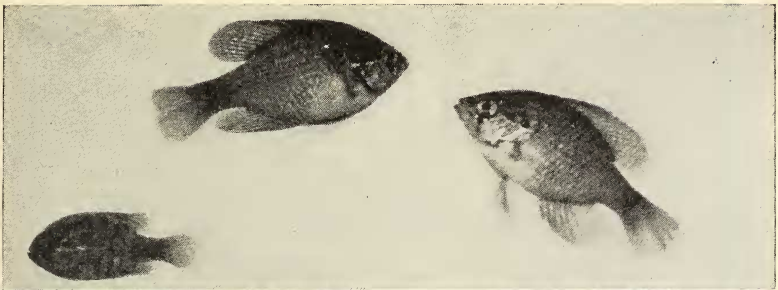


Fig. 324. Plant associations in pool shown in Figure 2. The dotted line encloses the area which was the chief habitat of *Enneacanthus*. The numbers refer to clusters of various plants as follows: 1. *Pontederia cordata* Linn.; 2. *Nymphaea advena* Aiton; 3. *Cephalanthus occidentalis* Linn.; 4. *Alnus incana* Willd.; 5. *Pyrus malus* Linn.; 6. *Acer rubrum* Linn.; 7. *Salix alba* Linn.; 8. *Cornus amomum* Mill.; 9. *Salix nigra* Marsh.; 10. *Philotvia nuttallii* (Plauch); 11. *Potomogeton epihydrus* Raf.; 12. *Valiseneria spiralis* Linn.



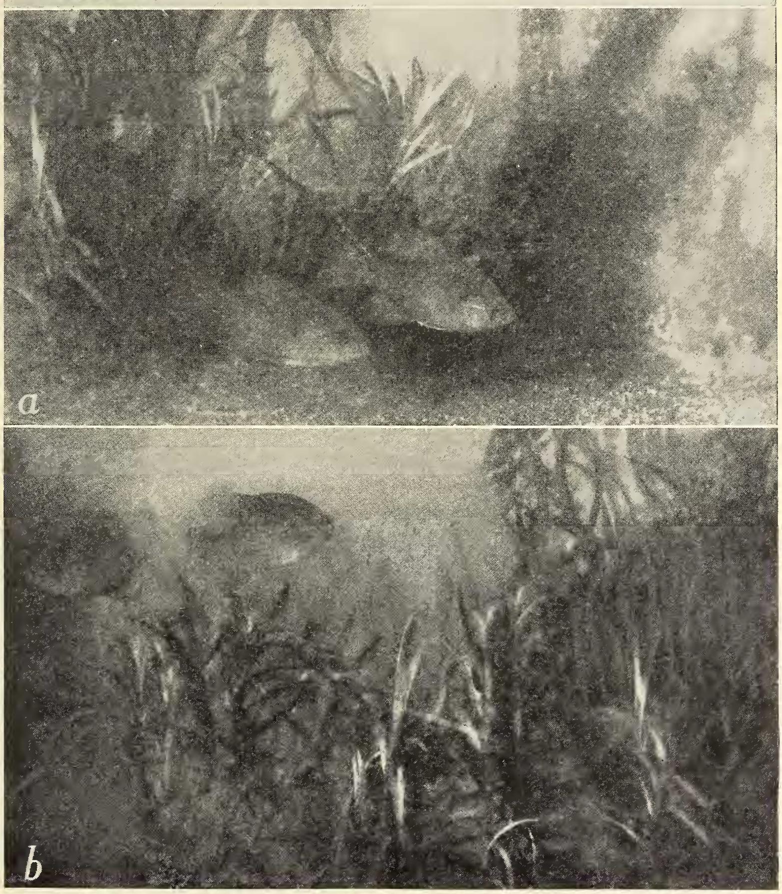


Fig. 325. *a*. Adult female and young on same scale. Photo E. R. Osterndorff.
Fig. 326. *a*, *b*. Males in an aquarium with a transplanted habitat.

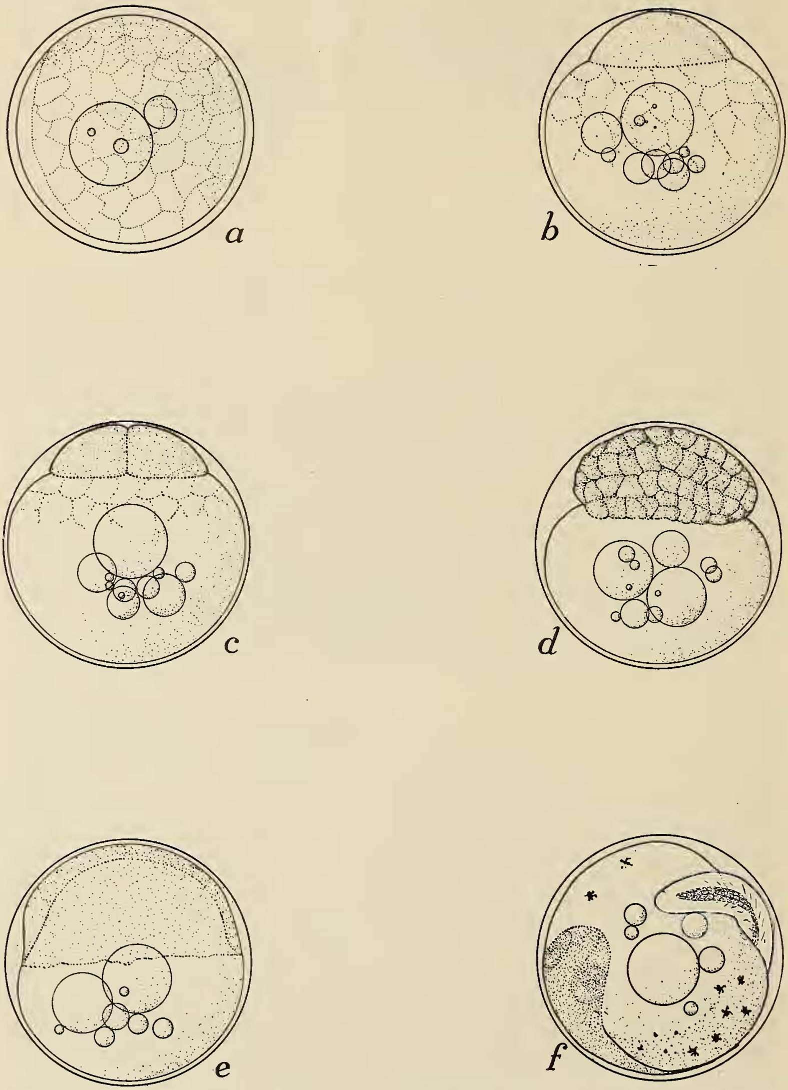


Fig. 327. Eggs of *Ennaecanthus; a.* Unfertilized egg; *b.* Blastodisc just formed; *c* 2-cell stage; *d.* Blastula in advanced stage; *e.* Egg showing advanced anterio-posterior differentiation; *f.* Egg just before hatching.

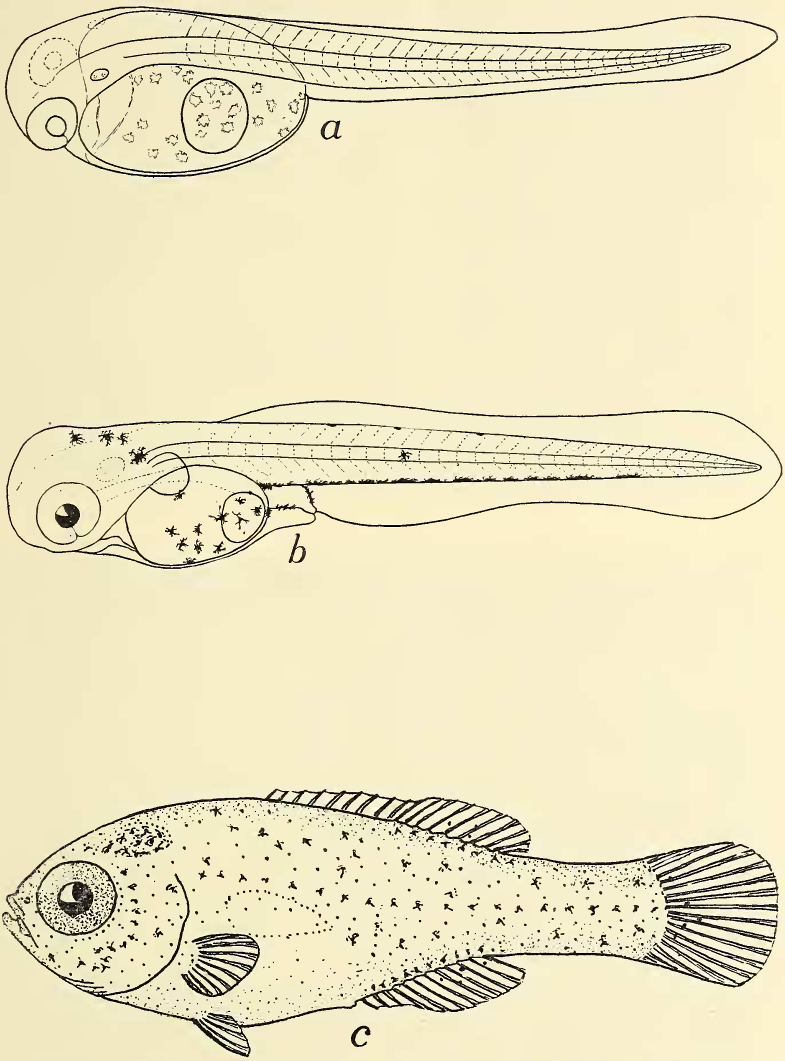


Fig. 328. Development of *Enneacanthus; a*. Newly hatched larvae, total length 3.25 mm.; *b*. Advanced larvae, total length 4.15 mm.; *c*. Advanced post larvae, standard length 9.0 mm.

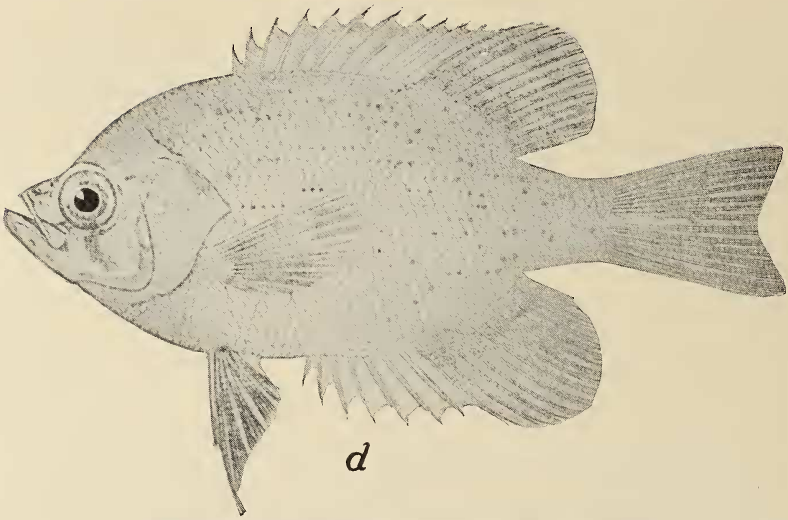


Fig. 328. Development of *Enneacanthus; d.* Adult fish.

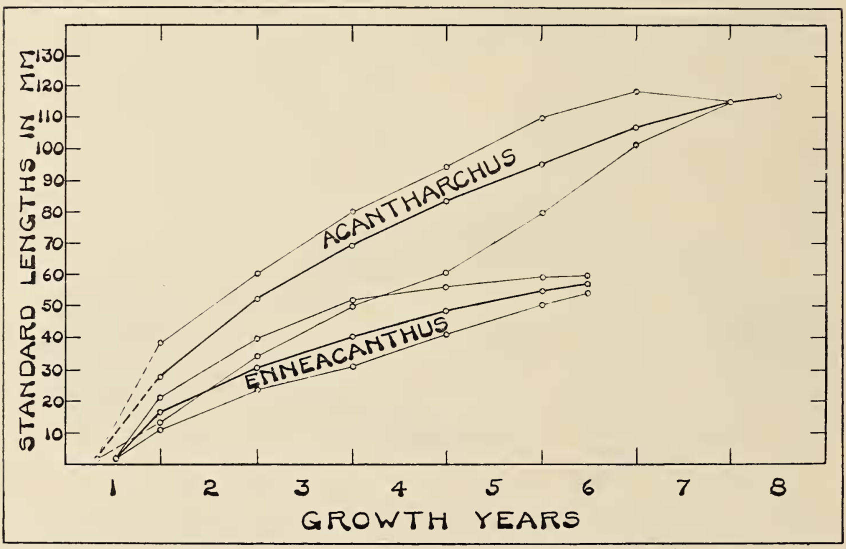


Fig. 329. Growth curve of *Enneacanthus* and *Acantharchus* based on scale examination. The heavy line represents the modal growth, and the light lines the extremes. The dotted lines in the *Acantharchus* curve represent the projected probable growth of the very young. The *Enneacanthus* curve is based on fourteen individuals, and that of *Acantharchus* on ten individuals.

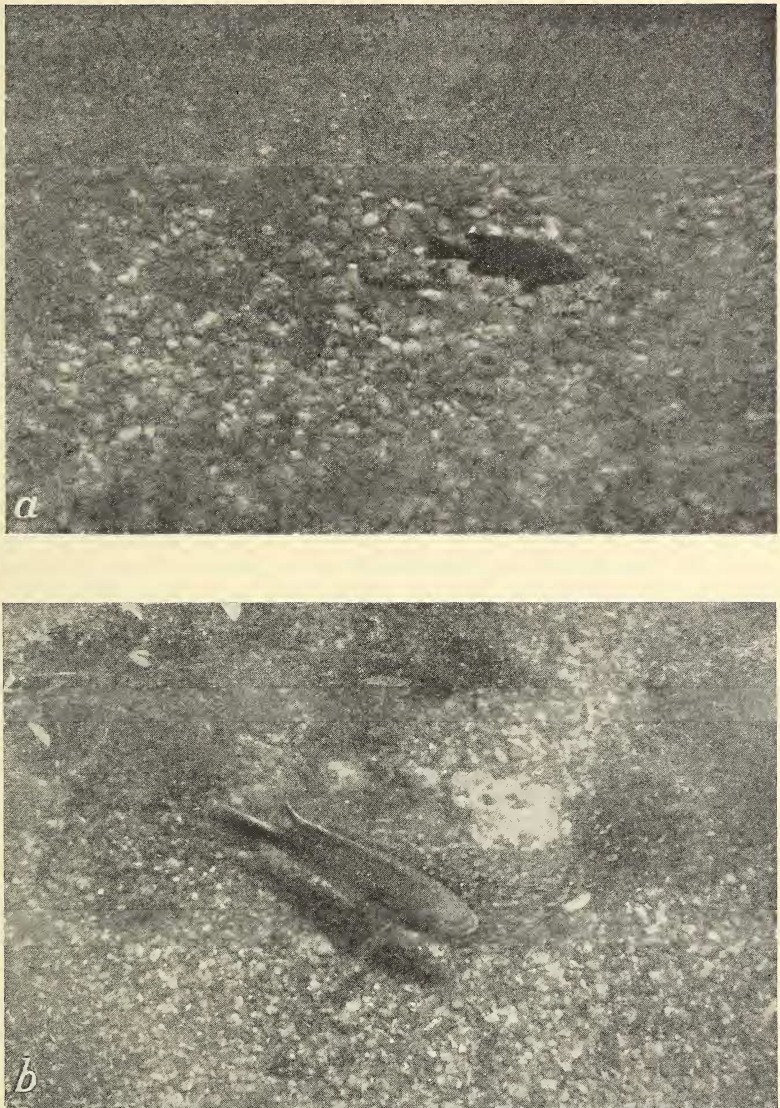


Fig. 330. *a*. Nest of *Eupomotis gibbosus* with parent on guard; *b*. Nest of *Lepomis auritus* with parent on guard.

They are less distinct over the light peritoneum, which shows through the semi-translucent flesh. This is probably of purely mechanical causes as these colors are doubtless due to light interference and not pigment and are consequently considerably dimmed by light coming from the opposite side. The ventrals and anal and to a slight extent the other fins and thoracic region are suffused with pink. When excited the general coloration becomes darker. When roughly handled as when caught in a seine they become a very deep olive blue and the lighter spots are glitteringly brilliant by contrast.

Mature females are a pale olive, preceptably more drab than their consorts. There are light spots on the scales but they lack the greenish tint of the males. Consequently their pattern of spots blends with the ground color and is all but lost in the general effect. There was one exception noted. The fins of this fish were suffused with pink in manner characteristic of the males. This color description of both males and females agrees in its essential aspects with that given by Hildebrand & Schroeder 1928.

Young fish up to and into their second year are a dusky olive and have about seven broad black bars on their sides. They have the conspicuous greenish spots on their sides, but these are not as bold as in the mature males nor do they form such distinct horizontal rows of dots. These fuse to make one large area of silver-greenish and blue on their cheeks. When these fish become disturbed their ground color gets lighter, particularly on the ventral surface which becomes practically white. Viewed from above they range from a dull sand color to steel blue. In an aquarium set with as near a natural bottom as possible this coloration rendered them all but invisible when viewed from above. The darker phase matched the color of decaying *Potomogeton* and the lighter that of a sandy bottom. The light and dark vertical bands of the immature blends well with a background of *Potomogeton epihydras.* Fishes up to 17 mm. s. l. are strongly barred and they do not begin to lose it before they are about 45 mm. Even the larger specimens, at times, show suggestions of these juvenile bars. Fig. 325*a* shows an adult female and a juvenile, and Fig. 326*a*, *b* represents two males in an aquarium with as near natural surroundings as could be arranged.

Spawning Habits

There must be considerable rivalry among the males as is evidenced by the somewhat ragged condition of their fins, principally the caudal, during the mating season. In other local sunfishes much time is spent in nest building and while there is considerable rivalry it seldom seems to come to actual combat. Bade states that *Enneacanthus* does not build a nest of gravel in an aquarium at least. Our observations, although the evidence is purely negative, leads to the same conclusion. In the absence of nests *Potomogeton epihydrus* was suspected of harboring the adhesive eggs. None could be found however, but this is not surprising when the irregularity with which the females develop roe is considered. Although we made collections for the purpose of stripping from July 3 to September 9, at no time did we obtain a large number of ripe females. There were always numerous green fish and usually some spent. In other words, the season is exceedingly protracted and does not come to a sharp peak. Judging from the appearance of the ripe females they probably release all of their eggs at one time. It would be interesting to determine whether this is the retention of a primative spawning habit or represents the loss of the nest building habit or a modification of it, on account of special conditions. A further study and observation of the actual spawning act should be well worth while together with a careful comparison with the more available nesting species.

The Eggs

The eggs of *Enneacanthus* are demersal and fairly adhesive. They are spherical and very constant in size scarcely varying from a diameter of 0.9 mm. The yolk is a very pale amber and contains a variable number of lemon yellow, highly refractive oil globules. These vary in diameter from 0.325 mm. down to a point where they are barely visible under the usual magnifications. A count of the oil globules of fifty-three eggs show the average number to be 7 + with a range of from 2 to 16. There seems to be no absolute correlation between size and number of oil globules. Usually each egg has several rather large globules (0.075 mm. or over) and a variable number of minute ones.

The development of the eggs is rapid. At a temperature of 73° F. they harden within twenty minutes after fertilization. By this time the germ disk is clearly delimited and the fragmentation of the yolk at first very pronounced has disappeared at the opposite pole. By thirty-five minutes a distinct groove has formed about the edge of the blastodisk. The first cleavage is completed in forty-five minutes, the second by eighty and the third by one hundred. Within three and one-half hours after fertilization the rapid growth of the animal pole has made the egg somewhat ovoid. The long axis averages about 0.096 mm. and the short about 0.090 mm. A distinct germ streak is visible at eight hours, with evident anterio-posterio differentiation. The blastopore closes within eleven and one-half hours. By twenty-one hours the embryo shows segmentation. They are occasionally moving and show cardial pulsations by forty-five hours. Some black chromatophores are also present by this time. Hatching occurs at about fifty-seven hours after fertilization. Fig. 327 shows six stages in the development of these eggs. As they are so typical of the group they represent, little need be said by way of further explanation.

Larvae and Post Larvae

The larvae average 2.3 mm. in length on hatching. The oil droplets consolidate shortly thereafter to form one large globule, which is situated on the ventral surface just a little forward of the posterior end of the yolk. Chromatophores are present on the yolk sac at hatching. They spread rapidly as development progresses. Larvae thirty hours old have a patch of them over the brain and the ventral artery is heavily pigmented for most of its length. Red corpuscles are evident in the blood. The pectoral fin appears at forty hours, the yolk shrinks noticeably and they are very active. They are positively heliotropic and swim up to the top of the water where they hang suspended from the surface film. By thirty-six hours the mouth is open and the yolk sac is nearly gone, but the fish usually still hang from the surface film.

Up to this time almost none died but at this point, as is usual with such fry under laboratory conditions, the mortality was sudden and nearly complete. The smallest specimen collected measured 8.2 mm. From the rate of growth of the laboratory specimens it was judged to be about a little more than two weeks old. At this size the caudal fin had distinct rays and was rounded. The spines and soft rays of the dorsal could be distinguished and counted,

TABLE IV. COMPARISON OF EGGS, INCUBATION TIME, AND EARLY GROWTH OF *ENNEACANTHUS* WITH OTHER SPECIES

PHYSICAL ATTRIBUTES OF EGGS

	Average Egg dia. mm.	Oil Globules		Yolk Color	Adhesion
		Number	Average dia. mm.		
Enneacanthus....	0.90	2 to 16 (average 7 +)	0.325 and less	Pale amber	Slight
Eupomotis.......	1.20	1 + some very small	0.40	Pale amber	Slight
Lepomis.........	1.80	1 + various smaller	0.60 and less	Bright yellow	Strong

INCUBATION AND AVERAGE LENGTH OF FRY AT VARIOUS TIMES

	Incubation in hours	Lengths in mm. hours after hatching			
		0	24	48	120
Enneacanthus....	57	2.30	3.22	3.43	4.50
Eupomotis.......	96	2.60	3.64	4.20	5.30

but it still had a vestige of a urostyle. Another specimen of 10.5 mm. showed none of these larval characteristics and was fundamentally similar to the adults except in the proportions of the body, depth, eye, head, etc. Fig. 328 shows four stages in the development of this species. Table 4 indicates the average rate of growth of the larvae.

Counts of the pulse were taken. It was at first high and showed a definite downward trend to the critical period. After

TABLE V. LEPOMINAE OF NORTHERN NEW JERSEY

	Acantharchus pomotis	*Enneacanthus obesus*	*Enneacanthus gloriosus*	*Mesogonistius chaetodon*	*Ambloplites rupestris*	*Lepomis auritus*	*Lepomis pallidus*	*Eupomotis gibbosus*
3	..	A	A	A	..	A	A	A
4	..	..	..	..	..	..	..	..
5	A	..	..	..	..	..	..	..
6	..	..	..	..	A	..	..	..
7	..	..	..	..	..	..	..	..
8	..	..	..	..	..	a	..	..
9	..	D	Da	..	..	a	..	..
10	da	da	Dd	Dd	da	Da	Da	Dda
11	D	..	..	..	..	d	da	da
12	D	..	..	a	D	d	da	d
Average no. scales..........	39	32	30	28	43	46	47	43
Caudal fin.................	Convex				Concave			

A—Anal spines. a—Anal rays.
D—Dorsal spines. d—Dorsal rays.

that it was naturally very erratic and doubtless abnormal. On hatching the heart beats ranged from 174 to 228 per minute with a mode at 218. They fell regularly to a mode at 124 on the fourth day. After this they became erratic so that on the sixth day they ranged from fifty to 200. On the seventh the larvae showed a heavy mortality.

Rate of Growth

Scales from almost all of the fish collected were examined for growth rings and the results when plotted gave a very reasonable curve. The fish apparently attain a length of about 15 mm. in the summer of hatching and are still of a very pale color when they winter over for the first time. They become barred early the next summer and attain a length of about 30 mm. by the end of that growing season. In the following season they are still barred but become sexually mature that season. Well developed gonads are regularly found in fish of this class and eggs obtained from two of them were successfully fertilized by a male of the next year class. No males in this class could be stripped however so males of the next year were regularly used as they could be at once recognized by their marked secondary characteristics. By the time their third winter is reached they measure from 40 to 50 mm. Only three fish larger than this were taken. They measured 55, 60, and 71 mm. and according to the scale markings were in their sixth year. The curve based on scale examination is given in Fig. 329.

Comparison with other Species

For purposes of comparison and identification of the Lepominae of this region various other data as collected is here recorded.

Eupomotis gibbosus.—The nest building of this species is too well known to need repetition. Figure 330*a* shows a typical one with the fish on it as viewed through the surface. Locally, nest building is in progress as early as the latter part of May and continues usually well into August.

The eggs average about 1.20 mm. in diameter and usually contain a single large oil globule and a few extremely minute ones scarcely discernable under ordinary magnifications. This large globule averages about 0.40 mm. in diameter and is a bright lemon yellow.

The eggs develop much slower than *Enneacanthus* requiring four days to hatch under similar conditions.

The larvae on hatching average about 2.60 mm. in length; 3.64 in twenty-four hours, 4.20 mm. in forty-eight hours and 53 mm. in five days.

Lepomis auritus. The period of nest building of this species practically coincides with that of *E. gibbosus.* Such a nest with its guarding parent is shown in Fig. 330*b*.

The eggs are extremely adhesive, much more so than either *Eupomotis* or *Enneancanthus* and are of a very bright yellow color which almost equals that of the oil globules. There is usually a single large one (about 0.60 mm. diameter) and a variable number of smaller ones of different sizes. These eggs are relatively large, averaging about 1.8 mm. in diameter. A comparison of these three types of eggs is given in Table 4.

Acantharchus pomotis. Although some attempt was made to obtain data on this species little of value was determined. No fish were found to be ripe at any time and no nests could be discovered. However, this is the least common species of the family in Post Brook. A curve of growth based on scale examination is given in Fig. 329. This does not appear to be entirely satisfactory but is consistent although it suggests a rather unusual type of growth.

This species appears to be largely nocturnal in habits. During the day time it was frequently found hiding under stones or submerged logs.

No data was collected on other species found in this region but the data given was found to be of value in connection with the standard keys in the differentiation of the post larvae.

Summary

1. Pond fishes may successfully invade old trout streams when the building of lakes further upstream renders such unsuitable for trout by raising the temperature and thereby reducing the limiting factor, oxygen, both by the direct effect of temperature and the indirect effect of encouraging the growth of oxygen consuming micro-organisms.

2. Such invading fishes naturally select the most pond-like area leaving the intervening rapids relatively barren of fish life.

3. *Enneacanthus gloriosus* selects the denser stands of aquatic plants for its habitat from which it seldom wanders very far.

4. It feeds largely on organisms to be found climbing about on these plants.

5. Males mature at a length of about 40 mm. and in the breeding season are very brilliant colored.

Females mature at a length of about 42 mm. and are usually barred vertically but are otherwise rather plain drab. The immature resemble the females.

6. *Enneacanthus gloriosus* apparently does not build a nest of gravel but deposits its adhesive eggs amid the weeds of its habitat. There is considerable fighting among the males.

7. The spawning season is protracted and reaches no distinct peak.

8. The eggs are typical of the sub-family Lepominae and average about 0.9 mm. in diameter and hatch in about 57 hours at a temperature of 73° F.

9. The larvae are about 2.3 mm. long on hatching and recognizable at a length of about 10 mm.

10. Maturity is attained by the second summer and the species may reach an age of six years probably spawning each year.

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